

## **USING INTERDISCIPLINARY LABORATORY EXPERIENCES TO TEACH TEAMWORK SKILLS.**

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### **Abstract**

With the integration of Total Quality Management (TQM) and World Class Manufacturing (WCM) philosophies into today's industrial environment, educational institutions have been asked by industry to incorporate more activities designed to develop skills related to working in teams. As a result many academic institutions have implemented team based laboratory activities. Since most industrial teams include individuals from different management and manufacturing disciplines (such as sales, engineering, manufacturing, purchasing and manpower planning), if the educational institution's efforts do not involve some type of interdisciplinary activities, much of the potential learning experience may be lost. Although developing team-oriented activities for a given class exposes students to some elements of group dynamics and teamwork, such activities fall short of the objectives of the industry's request. This is because the higher-level technical courses have prerequisites, resulting in all members of the team having similar academic backgrounds and academic objectives for the tasks.

This paper describes how and why Purdue University's School of Aeronautics and Astronautics (Engineering) (AAE) has joined forces with the Aeronautical Technology Section (AOT) of the University's Department of Aviation Technology (AT) on experimental basis to provide senior level students with a design/build/test experience in an interdisciplinary team environment. The paper identifies the two types of projects (specific objective and research) used in support of interdisciplinary activities. It describes previous projects and discusses some of the successes and difficulties experienced in pursuit of this effort. Industry's reaction to these interdisciplinary team activities is discussed, as well as, future plans for the expansion of interdisciplinary design/build/test team projects.

### **Introduction**

Purdue University provides a unique combination of associated fields of study. Among these fields of study are the Schools of Engineering and the School of Technology's various departments. Although each School includes theoretical and application techniques in its curriculum, the Schools of Engineering generally speaking concentrate on the theoretical application of science and engineering principles, while the Departments of Technology focus on the application techniques related to these principles. Among these schools and departments are

the School of Aeronautics and Astronautics<sup>1</sup> (Engineering) [AAE] and Department of Aviation Technology<sup>2</sup> [AT].

The Aeronautics and Astronautics curriculum concentrates on the fundamental subject areas necessary to the research, development, design, and operation of the aerospace industry. The curriculum is structured to emphasize the use of design tools of aerodynamics, propulsion, structures, dynamics, and control systems, and further provides design courses to integrate these disciplines into the design of flight vehicles that will perform the required mission.<sup>3</sup> A major priority of Engineering education, therefore, encompasses the managing of engineering principles. The transition of those engineering principles to the applications level is not within the purview of AAE's accredited engineering curriculum.

The Aeronautical Technology [AOT] section of Aviation Technology prepares students for positions in the aerospace manufacturing and the aerospace vehicle support industries. These positions translate engineering models into formats and processes compatible with the user's needs. Focus is placed on the process of integrating the product design across the complete spectrum of users' needs. This integration involves facilitating the interaction of user's needs in terms of manufacturing details, operational requirements, personnel needs, design support forecasting, supportability management, and cross-functional coordination of the users in the organizational systems. These applications requirements require a much higher degree of cross-functional application knowledge and ability to understand many different industrial needs models, than what can be offered in the typical Engineering curriculum. Theoretical design models and the use of design tools are not within the scope of the Technologist.

Academic requirements in AOT include: technical courses at the direct application level; communications and management coursework designed to teach the interdisciplinary skills necessary to integrate the cross functional needs of the wide variety of user/customer needs. Successful completion of the AOT curriculum meets the requirements of the Federal Aviation Administration (FAA) under Federal Air Regulation (FAR) Part 147 for eligibility to obtain Airframe and Powerplant Mechanic Certifications.

Each discipline (AAE and AOT) has course work that incorporates teamwork activities. There are five (5) such courses offered in AAE of which two are required<sup>4</sup>. AOT has twelve (12) that incorporate team activities. Eight (8) of these are required courses. With the exception of two courses in each discipline however, each activity is directed toward a common goal and is performed by individuals with the same basic academic background and orientation. These two interdisciplinary courses are the focal point of this paper.

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<sup>1</sup> <http://aae.www.ecn.purdue.edu/AAE/>

<sup>2</sup> <http://www.tech.purdue.edu/>

<sup>3</sup> <http://aae.www.ecn.purdue.edu/AAE/Welcome/Index.html>

<sup>4</sup> <http://cartoon.ecn.purdue.edu/~aae490t/papers/reno2000-0525b.doc>

## History

In the fall of 1995, as a response to prompting by industry, the first efforts to combine engineering and technology students in a common laboratory design/build/test activity came to fruition. In each of the following fall semesters this effort has been duplicated, with some change to the project and its objectives but consistently using the same organizational (team working) structure.

In this environment, each class had its own academic objectives but share the common laboratory assignment. Students are randomly assigned to teams consisting of a balanced combination of engineering and technology students based upon the number of students enrolled in each course. Each team is given the same design/build test objectives. Although the weight of the project assigned to each of the classes grading systems may vary, the percentage grade (i.e. the percentage of available points) applies to all students in a team. In practice the weight given in each of the classes ranges from twenty (20%) percent to thirty-three (33%) percent while both classes use the interdisciplinary project as the focal point of its Final Exam testing.

Over the last four years, the technical objectives of all the design/build/test activities included beam type structures that must:

1. Withstand a given load with a maximum deflection and no permanent deformation and a maintain minimum load carrying capability,
2. Fit within defined physical restraints and
3. Be fabricated from a given list of materials.

In some instances the assembly must be capable of being stored in a container that has significantly smaller physical dimensions than the assembly. Additionally, time limits for disassembly and installation of the product are established. In another project the assembly collapsed into given dimensional requirements. The design/build/test requirements for the Fall 2000 design/build/test product were similar to those of the past with an additional requirement that the beam structure contain another component in a watertight environment with a maximum time requirement for the installation of the component into the beam assembly.

Once the teams are assigned, they met in the laboratory manufacturing facility where the engineering students were introduced to the equipment to be used in fabricating the product. The purpose of this meeting was to help the AAE student understand the limitations of the manufacturing capabilities of the facilities while developing a relationship with their AOT counterparts.

The teams are then to accomplish preliminary design and analysis work, presenting their proposed designs in a scheduled formal presentation. Both class instructors, invited guests and supporting graduate students are present at this formal presentation. Typically all class members are in attendance during the formal presentation and are permitted to ask questions of other teams. A list of comments and concerns is then compiled and then relayed to each team before a final proposal is submitted. The final proposal must include a bill of material, engineering and production drawings, manufacturing process sheets and a purchase order for materials and any special tooling required. Although the different materials requested by individual teams are combined for economic reasons into a single purchase order, each team must for the purpose of

financial analysis comply with the vendor's minimum purchase requirements. It is interesting to note that upon occasion the prescribed vendor has been "out-of-stock" resulting in last minute redesign requirements.

The products are then constructed and tested. A final written report is submitted and oral presentations are made during finals week.

The projects are evaluated based upon:

1. Ability to meet design load carrying requirement;
2. Dimensional requirements;
3. Assembly and disassembly times;
4. Cost;
5. Weight
6. The design's "Buy to Fly" weight ratio and
7. The quality of the final report.

Although records of manufacturing man-hours are maintained, they are not a part of the project evaluation process since the engineering students are encouraged to participate in the manufacturing process.

### **Expansion of Interdisciplinary Design/Build/Test Projects into Research**

Beginning in the spring semester 1999, an additional independent study opportunity was added by AOT to expand the student's manufacturing experience and at the same time support AAE student research projects. This effort again consists of two independent courses that share the same research activity. Both courses are student electives and the interdisciplinary research projects are the focal point of each class.

At the beginning of the semester students from each school (AAE and AOT) are introduced and potential research projects are identified. Beginning with the second offering of the class, previous research projects are discussed as well as related areas for expanded research. The students then organize themselves into teams of common research interest and present proposals for research projects. Once approved, a timetable for each research project is established and approved by the instructors.

Unlike the interdisciplinary laboratory project offered in the fall semester that requires metal working skills, the spring semester research project typically involves more advanced use of machining processes (CNC and CAD/CAM application) and the use of advanced composite materials including the design and fabrication of related molds.

The favorite selections by students for research projects are micro-air vehicles and aerofoil design for specific applications. Other research projects have included: an electric powered pylon racer airplane; a C-Wing project; a turbine for H<sub>2</sub>O<sub>2</sub> propellant; ground effects in motorcycle racing, a convergence nozzle design for alternative rocket fuels.

## **The Student Team Working Learning Experience**

In addition to the increase in technical knowledge generated by each activity, both the fall (interdisciplinary common project) and the spring (interdisciplinary research project) activities have generated the same types of teamwork experience for the students regardless of their field of study. Semester exit interviews have generated consistent comments regarding an increased recognition of the value of in-depth planning, coordination and constant communication.

In addition there seems to be an increased respect for the others' discipline. Typically at the beginning of the semester, students who have not had prior interdisciplinary teamwork experience tend to fall into either of two attitudinal extremes. They feel that they are either capable of doing the other team members' primary function or that they have no capability to fulfill the primary function of the other team members. By the end of the semester project, in addition to students having a greater confidence in their ability to participate significantly in the others' activities, they more importantly have generated an increased respect for the free and frequent exchange of information, ideas and concerns between the disciplines.

## **Acknowledgement by Industry**

Industry has acknowledged support of the interdisciplinary design/build/test academic experience not only through its financial support, but also its communication with students, particularly during its student interview process. One student reported that upon learning of his participation in the interdisciplinary design/build/test project early in an employment interview, the interviewer spent the majority of the interview in a discussion of the project and the student's related learning experiences.

In addition, industrial financial support from such companies as Boeing Corporation and Allied Signal/Honeywell/GE have defrayed the related material and tooling costs and have offered prize money for the most successful project. Another engineering company has supported these efforts through an endowment that bears the majority of the cost of staffing and operations for "engineering/technology integration" activities.

## **Difficulties in Pursuing Interdisciplinary Activities**

Experience has shown three major difficulties in pursuing interdisciplinary design/build/test activities. They are student/team scheduling, student preconceptions and attitudes and student preparedness.

Initial class scheduling problems have been relatively easy to resolve. However, since these activities (particularly in the fall semester – interdisciplinary common project) often require outside scheduled class hour contact between students, coordination of student availability during non-class hours now appears to be a consideration in team assignments. It is believed that the random assignment of team members is an important component of the overall interdisciplinary experience. Therefore, a system that maintains a degree of randomness, while considering student availability, needs to be developed.

Student preconceptions and attitudes regarding skills and abilities of students in the other course of study can create difficulties to maximizing the teamwork experience. Much of this may come from the historical “division of labor” organizational philosophies. Another is the preconception that one course of study is more difficult than the other, leading to an informal hierarchy. Compounding these preconceptions is that the random selection of team members may generate teams in which a stronger student from one discipline is teamed with a weaker member of the other discipline. For the stronger students this situation could tend to validate their preconceptions.

Although preconceptions and attitudes are identified as difficulties, it is the frequent existence of these preconceptions and/or attitudes that generates the need for interdisciplinary teamwork experiences in an academic environment. Whenever preconceptions and attitudes were present in a team’s membership, by the end of the semester the majority of those teams recognized that it was these preconceptions and attitudes that limited their team’s success. As a result, a major (if not primary) objective of providing an interdisciplinary teamwork experience has been fulfilled. The inclusion of preconceptions and attitudes in the list of difficulties is because their presence lessens the opportunity for other interdisciplinary teamwork learning experiences and therefore ways of lessening their impact need to be identified. The expansion of the program, which is discussed later, is the initial attempt to lessen the effect of preconceptions and attitudes.

Finally, in the current environment, students learn necessary technical skills in the same semester as they are expected to exercise them in an interdisciplinary teamwork experience. Although, this provides reinforcement for lecture presentations, it means that during the early portions of the term little or no interdisciplinary interaction takes place. In the current activities, some interaction takes place through capabilities orientation exercises discussed previously, however, little else is accomplished during the early portion of the academic term. In a practical sense, this can best be improved by incorporating interdisciplinary activities in a capstone type course.

### **Broadening Interdisciplinary Participation.**

It is believed that broadening a student’s exposure to interdisciplinary experiences will increase the benefits of an interdisciplinary teamwork based program in two respects. First, students need earlier and more frequent exposure to interdisciplinary activities. Secondly, as the frequency of interdisciplinary teamwork activities increases, the number of different disciplinary orientations needs to increase.

Earlier exposure to interdisciplinary teamwork activities may tend to lessen the impact of the “preconceptions and attitudes” exhibited by some students. Since “preconceptions and attitudes” tend to be self-correcting with the interdisciplinary experience, an earlier exposure may allow the effected student, through practical experience, to develop the more appropriate perspective earlier in their academic career, thus providing an expanded opportunity for other related learning experiences. Frequent exposure to interdisciplinary may also lessen the reinforcement of preconceptions and attitudes that result from the stronger/weaker student combination. Efforts are currently underway to include on a routine basis interdisciplinary teamwork based laboratory activities in the lower level “required” coursework in each curriculum.

To date, only two academic areas of study are interacting in interdisciplinary teamwork activities. Although they are somewhat different orientations, they are closely related because they both deal with the more technical aspects of the activity. Additional orientations need to be brought into the interdisciplinary mix. "What level of quality needs to be produced? What will it cost? Can this 'better mousetrap' be marketed?" Because these other concerns affect the overall success of an activity in industry, they must eventually be included in a comprehensive interdisciplinary teamwork activity if an industry-like experience is to be attained.

Increasing the number of disciplines involved in an interdisciplinary teamwork project increases the complexity of its coordination. For that reason, the introduction of another discipline will be done first in the upper-division course (the higher level of academic involvement). In this case, this means the interdisciplinary research project. As experience is gained in the inclusion of other disciplines they may be incorporated at lower levels activities.

In the spring semester of 2001, an effort is being made to broaden the interdisciplinary teams to include a third "technical" discipline, Computer Graphics, taught at Purdue University. The Computer Graphics students will help introduce the capabilities of IBM's CATIA software into the design mix.

## **Bibliography**

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William A. Watkins is an Associate Professor in the Aviation Technology Department at Purdue University. He is a co-author of the Glencoe Division of Macmillan/McGraw-Hill's "Aircraft Maintenance and Repair, 7e." And is acknowledged by the FAA in its Advisory Circular 43.13-1b, "Acceptable Methods, Techniques, and Practices-Aircraft Inspection, Repair and Alterations," for his contributions to that document. He was named by the Aviation Technician Education Council as the "2000 Aviation Maintenance Educator of the Year."

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